Finite Element Modelling and Analysis of Hot Turning Operation

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

B. Tech.

(Mechanical Engineering)

By

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NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

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Certificate

*This is to certify that the thesis entitled " **Finite Element Modelling and Analysis of Hot Turning Operation.** " submitted by **Swayatt Behera (109ME0361)** in fulfillment of the requirement for the award of Bachelor of Technology Degree in Mechanical Engineering at the National Institute of Technology, Rourkela (Deemed University) is a genuine work carried out under my supervision.*

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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PLACE:

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ABSTRACT:

There is a need for materials of high hardness and resistance to cutting. As we know the machining of these materials has always been a great challenge. Machining of these alloys and materials required for cutting high-strength, which sometimes is not economical and sometimes even impractical. And even the non-conventional processes are generally limited to the point of view of productivity. The advantages of easy component manufacturing of excessive hard materials can be substantial in terms of reducing costs and lead times machined compared to the traditional one involves the heat treatment, grinding and manual finishing / polishing. In the hot working at a temperature of workpiece is increased so as to reduce its shear strength. This paper will focus on hot working of high manganese steel with petroleum fuel. Several parameters, such as cutting speed, feed, depth of cut and the temperature of the workpiece are taken. An experiment was conducted. Even the machining process was simulated in ANSYS and DEFORM 2D to find corresponding deformation, rate of tool wear, cutting force and the temperature distribution.

Keywords: hot machining, non-conventional processes, feed, tool wear

CONTENTS: PAGE NO

List of Tables:

List of Figures:

Chapter 1

INTRODUCTION

Chapter 1

1.1 Introduction:

When the technology of mass production began with the transfer lines from Henry Ford, there came into being the fundamental techniques of working. Any working consumes throughout the world a large amount of money every year. A lot of material is wasted as scrap or chip formation [1]. Using the correct choice of tooling and processing conditions one can use this and greatly reduce processing costs. From the industrial point of view, the most important aspect is the cutting of metal is machinability and its influence on the economy of the process. Machinability has received much attention from researchers. One of the main objectives of the process is the production of materials more economically. A wrong decision can result in expensive production costs and reduces the quality of product [2].

In recent times the manufacturing industries have tried to reduce operating costs while improving the quality. In manufacturing, quality of cutting costs and improving the product are necessary steps to take in an increasingly competitive world, where investors require a higher return on investment. Many manufacturing processes involve some aspects of the operations of cutting, in which there is the need to estimate quantitatively the technological performance of machining operations such as tool life, strength, power and surface finish. This information is necessary for the performance of the selection and design of machine tools and cutting tools, as well as the optimization of cutting conditions for the efficient and effective operations. The most important factor for the successful continuation of production in a typical operation is the wear of cutting tools in metal.

During the last two decades, there has been a considerable industrial interest in the machining of hard to cut. With the advancement of science and technology, there is a need for materials of high hardness and shear strength in the market. The production of exotic materials and intelligent materials has become very essential to meet the strength requirements for the aerospace and defense industry [3]. The production of super alloys and hard materials has become extremely essential to meet the design requirements for critical aerospace and defense industry. The processing of these materials has always been a great challenge for production engineering. These materials are used in the production of components for electrical, chemical, dental orthopaedics, nuclear and aerospace industries, where high dimensional accuracy, tool life and surface roughness of a satisfactory quality [4]. Components of production beneficial excessive hard materials can be substantial in terms of reduction of processing costs and lead time as compared to the traditional way, which provides for the machining of metals in heat treatment followed by annealing and then the finishing operations, such as grinding operations and polishing, which in turn, consumes a lot of effort, time and work space.

It is also difficult to obtain a good surface finish and tool life while working with materials having high strength, corrosion resistance, toughness, and wear resistance in conventional machining. Processing of these materials requires cutting tools high strength, which is very expensive, and sometimes even impossible. Non-conventional machining process, other practicable means, is mostly limited to low scale removal of material. For the removal of bulk material, the growing interest in the process of hot working is being developed in the industry. In this method, the workpiece is softened by heating and consequently the cutting force is reduced [5].

1.2 Hot machining:

Tigham first innovated the process of hot machining in 1889, since then it has created much interest among various investigators.

Hot machining operation is a machining method conducted on conventional machine tools in which work piece is preheated before cutting operation to become softer and thereby to reduce its shear strength. The high operating temperature in hot turning process imparts softness on the material under investigation, which eases the machining process and further reduces the high cost of changing and sharpening cutting tools. Softening of the workpiece in hot machining is a more effective method than strengthening the cutting tool in conventional machining [5]. Earlier research has shown that the selection of a proper heating method eliminates the undesirable structural changes in the workpiece and reduces the machining cost. For machining of hard-to-cut steel, the cutting tools materials must be harder than workpiece materials. Due to expensive cost of cutting such materials, the different machining methods are being used. Usually, formation of second phase particles makes the alloy both stronger and more abrasive and thus more difficult to machine [4]. Advantage, therefore, lies in machining in the soft state.

Some remarkable effects of hot machining operation are.

- Tool life increases.
- Cutting forces are less.
- Less power consumption.
- Greater productivity due to higher MRR.
- Strain hardenability and flow stresses in work piece are reduced.
- Wear and abrasion of cutting tool is less resulting greater tool life.
- Better surface quality.
- Hot Machining of brittle ceramic materials is very much easier than any other known approaches.

1.3 Materials:

The materials which are generally machined by hot machining operation are hardened steel, High Manganese steel, NH4 (Ni-hard steel), Superalloys, High Chromium white CI, Ceramic Materials, Hyperchrome CI alloys, Cr-Mo white CI, Stainless Steel, S-816 alloy, X-alloy, Timken 16-25-6, Navy Grade Steel, Inconel-X, Ni-Cr Steel and alloys of tungsten, molybdenum, titanium and tantalum.

1.4 Heating Methods

The process of hot working requires the selection of a suitable method for heating. The area or the zone affected by the heat should be as small as possible. The heat should not penetrate very deep within the surface of the material in hot working. At a much higher temperature metallurgical changes occur, then overheating is always undesirable and should be avoided. The various ways of preheating of the workpiece to heat are:

- Furnace Heating
- Resistance Heating
- Flame Heating (oxy-acetylene, oxy-LPG)
- Arc Heating
- Plasma Arc Heating
- Induction Heating
- Laser Assisted Heating
- Radio Frequency Heating Apparatus

1.5 Basic Requirements and Precautions of Heating the Workpiece:

• Heat applied should be localized in the cutting zone that is just in front of the cutting edge, where the deformation of the workpiece material is maximum.

• Heating should be limited to a small area thus limiting expansion of work piece, so that the dimensional accuracy can be tolerated.

• The method of supply of heat should be such that the limitations imposed by the size and shape of the workpiece, and machining conditions are minimal.

• Machined surfaces must not be contaminated or overheated, resulting in metallurgical changes that can produce distortion to the uncut material.

• The heat source must be able to provide a great contribution to specific heat to create a rapid response to temperature in front of the tool.

• The heating system used must be low initial investment and operation and maintenance.

• Safety should be given priority and is absolutely essential that the method used is not dangerous for the operator.

• The temperature control device must have high degree of accuracy.

Chapter 2

Finite Element Analysis

Chapter 2

2.1 Introduction to Finite Element Analysis:

Finite Element Analysis (FEA) was developed in 1943 by R. Courant, who used the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions for systems of vibration. Shortly after, an article published in 1956 by MJ Turner, RW Clough, HC Martin, and LJ Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deformation of complex structures”.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in the design of new products, and refinement of the existing product. A company is able to verify a proposed design and will be able to perform the specification of the client before fabrication or construction. Modifying an existing product or structure is used to qualify the product or structure of a new condition of service. In the case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in the industry: 2-D modeling, and 3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to be performed on a relatively normal computer, it tends to give less accurate results. 3-D modeling, however, it produces more accurate results sacrificing the ability to run on all computers faster, but actually [6].

Development of the finite element method (FEM) in the early 1970s pioneered the first simulations of orthogonal machining process. First research work used as a self-development of finite element code. Since 1990 starts massive use of commercial software, which is able to model the process, as NIKE2, ABAQUS / Standard, MARC, ABAQUS / Explicit, deform 2D FLUENT, FORGE 2D, ALGOR, LS DYNA [7].

Finite Element Method (FEM) modeling and simulation of manufacturing processes based is continually attracting researchers to a better understanding of the mechanisms of chip formation, heat generation in the areas of cutting, tool-chip interface friction characteristics and integrity on the machined surfaces. Forecasts of the physical parameters such as temperature and stress distributions play a key role with precision machining processes predictive process engineering. Tool edge geometry is particularly important because it is influence on tool life to achieve more desirable surface integrity is extremely high [8]. Therefore, the development of FEM models based on continuous, accurate and sound characteristic are needed in order to study the influence of the cutting edge geometry, mechanisms of tool wear and cutting conditions on the surface integrity and residual stresses on the machined surfaces. This paper aims to predict cutting forces, temperatures and residual stresses on the machined surface.

FEM has some advantages, as it solves problems of contact, bodies of different materials are used, curvilinear region can be approximated by finite elements or described accurately, etc. There are two types of formulations finite elements to describe a continuous medium: Lagrangian and Eulerian.

The Lagrangian is widely used. In an analysis of Lagrange, grid mesh deforms with the material, while in the Eulerian analysis grid is fixed in space. The Lagrangian analysis simulates the entry, exit, stages of intermittent and discontinuous chip formation, while the Eulerian cannot simulate the phases of intermittent and discontinuous chip formation. However, the Eulerian formulation eliminates the need for a chip criteria of division and to avoid distortions of the mesh [9].

In this project work modelling and analysis is done using **ANSYS** and **DEFORM-2D**.

2.2 Steps Required for Modelling and simulating a turning process:

[9]

2.2.1 Process setup and conditions:

Before modeling and simulation, the user must set the starting data, i.e. the parameters and process conditions: cutting speed, depth of cut, feed rate, the ambient temperature, if a cooling liquid will be present or not and coefficient of friction. These parameters will be described and set in the first step, pre-processor. When setting the conditions of the process, the user must choose the ambient temperature, coolant with the convection coefficient, friction factor and cutting heat transfer coefficient.

2.2.2 Tool and workpiece setup:

For the configuration tool, the user has two options. First, the user can choose the geometry of the tool from the libraries of software tools. Second, if the tool geometry is complex, such as a drill or a milling insert, this can be imported from CAD systems. There should not an area without free edges, no corners are not valid and invalid guidelines.

2.2.3 Boundary conditions:

The boundary conditions help the user to determine the interaction of the piece with other objects in the simulation. The boundary conditions are most often used: heat exchange with the environment and the speed in contact between objects in the model, etc.

2.2.4 Tool and workpiece material:

A material should be assigned to the tool and another for the piece. The material can be loaded from the library, starting from aluminum and materials beta up to steel and superalloys, including composites. Most of the tools are made of carbide or toilet. If the user requires a special material, the software gives the possibility to create it. The user needs to know some properties of the material.

2.2.5 Mesh generation:

FEM uses Lagrangian or Eulerian meshing criteria. The mesh of Lagrange is reformulated in almost each time step, in order to handle the deformation of the material. If a crash simulation, for any reason, a new simulation can start where the other stopped. The tool and the workpiece meshing are very important for a process simulation accurately. A finer mesh gives a finer granularity. If the number of elements increases, also increases the time.

Meshing the piece is much more important. In general, pieces are modeled as objects made of plastic, can be easily deformed and cut by tools. When the mesh deforms, must be frequently regenerated. During the simulation, the mesh helps the reconstruction of distorted material.

2.2.6 Simulation controls and database generation:

The end of the pre-processor and also the beginning of the simulation step contain controls simulation and generation of database. The simulation commands, i.e. the number of simulation steps, step size to save, and calculation tool wear are the latest data pre-processing that needs to be set prior to running the simulation.

The tool wear can also be calculated. The structure and properties of the material affect the cutting forces and therefore the rate of wear. Tool-chip interface means first of all cutting parameters, friction, and coolants, these reducing tool wear and cutting temperature if they are set correctly. The instrument must be appropriately chosen for a transaction subject to the FEM modeling and simulation (turning, drilling, and milling). The optimal performance of a tool, a proper combination between the cutting conditions and the properties of the instruments.

Chapter 3

Literature Review

Chapter 3

Literature Review:

Studies of metal cutting are as old as more than 100 years. Early research in metal cutting is started with Cocquilhat (1851), which was focused on the work required to remove a given volume of material in drilling [10]. Tresca (1873) first attempted to explain how they are formed chips [11]. Ernest and Merchant (1941) have developed the first model of the simplest and most used for cutting. Lee and Shaffer (1951) [12], Kobayashi and Thomsen (1962) contributed to the study of Ernest and Merchant [13]. Oxley and Welsh (1963) introduced the first model of shear zone with parallel sides of the chip formation process for a predictive theory [14]. Books are the most popular text written by Armerago (1969), Boothroyd (1981), Shaw (1984) and Trent (2000). Knowledge more general introduction can be found at the textbooks written by Kalpakjian, et al. (2006), and DeGarmo, et al. (1997).

Finite element method has a wide use in modeling orthogonal (2D) and oblique (3D) metal cutting. Klamecki (1973) has developed one of the first finite element models for metal cutting processes using a Lagrangian elasto-plastic three-dimensional model to date has been limited to the early stages of chip formation [15]. Usui and Shirakashi (1982) have developed the first two-dimensional FE simulation of orthogonal machining using a particular calculation method called iterative method convergence to obtain solutions for the cutting of the steady state [16]. Iwata, et al. (1984) have developed a method for numerical modeling of the shear plane orthogonal to the stationary state on the basis of rigid plastic material model where temperature effects were neglected. Strenkowski and Carroll (1985) developed a numerical model for the orthogonal cut without chip preformed. Their model was based on a large deformation updated Lagrangian code [17]. Komvopoulos and Erpenbeck (1991) introduced a criterion of separation chip using the argument of the tolerance criterion distance to investigate the chip formation [18]. Lin and Lin (1992) have introduced a criterion of separation of chips using the subject of deformation energy, and have studied the geometry of the integrated circuit, the residual stresses in the machined surface, the temperature distribution in the chip, the tool and cutting forces [19]. Ceretti (1996) has developed a model of cutting eliminating elements have reached a critical value of accumulated damage. With the developments of hardware and commercial FE codes, limitations of modeling and computational difficulties have been overcome to some extent, many researchers focused on particular topics of cutting metals [20]. Bil, et al. (2004) compared three codes used in commercial FE simulations of metal cutting 2D, MSC Marc, ThirdWave AdvantEdge and 2D deformation by comparing the experimental results with the simulation results [21]. Özel (2006) and Filice, et al. (2007) [22] used Deform 2D to study the effects of different models of friction on the results of cutting. Attanasio, et al. (2008) included an advanced approach to model heat transfer phenomena tool-chip interface in the numerical simulation to investigate the tool wear by deformation 3D [23]. Davim and Maranhao (2009) used MSC Marc investigate the effects of plastic deformation and plastic strain rate during high speed machining (HSM) [24].

Table 3.1: History of cutting processes modelling [25]

	Analytical Methods	Experimental Methods	Mechanistic and Numerical methods
Before 1960	1941 Martellotti 1944 Merchant 1956 Dio, Salje 1958 Tobias	1944 Kasharin 1946 Sokalov 1956 Trigger	-
1960's	1960 Albrecht 1961 Albrecht, Gurney 1963 Zorev , Trusty 1969 Kegg	1963 Oxley , Zorev 1964 Pekelharing 1966 Thomas, Das 1969 Peters	1961 Sabberwal 1961 Koenigsberger 1962 Sabberwal

1970's	1974 Hannas, Oto 1976 Szakovits	1970 Knight 1972 Nigm 1974 Tlusty 1975 Pandit , Baily	1971 Okushima 1973 Klamecki 1974 Shirakasi, Tay 1979 Gygax
1980's	1981 Trusty 1985 Rubenstein 1986 D.W. Wu 1989 Oxley	1981 Komanduri 1984 Shi, Shin 1985 Ahn, et.al 1986 Pandit 1987 Ahm	1980 Lajczok 1982 Usui 1987 Riddle 1988 Carroll 1989 Yang
1990 to present	1993 Minis 1995 Altintas 1996 Arsecularatne 1998 Waldorf 1999 Moufki 2002 Becze, Elbestawi		1992 Yang 1993 Wayne 1994 Athavale 1995 Shih 1999 Ng et. Al

Chapter 4
Experimental Setup

Chapter 4

4.1 Experimental Setup:

The experiment was conducted on a central lathe. The following figure (4.1) shows the schematic diagram of a central lathe.

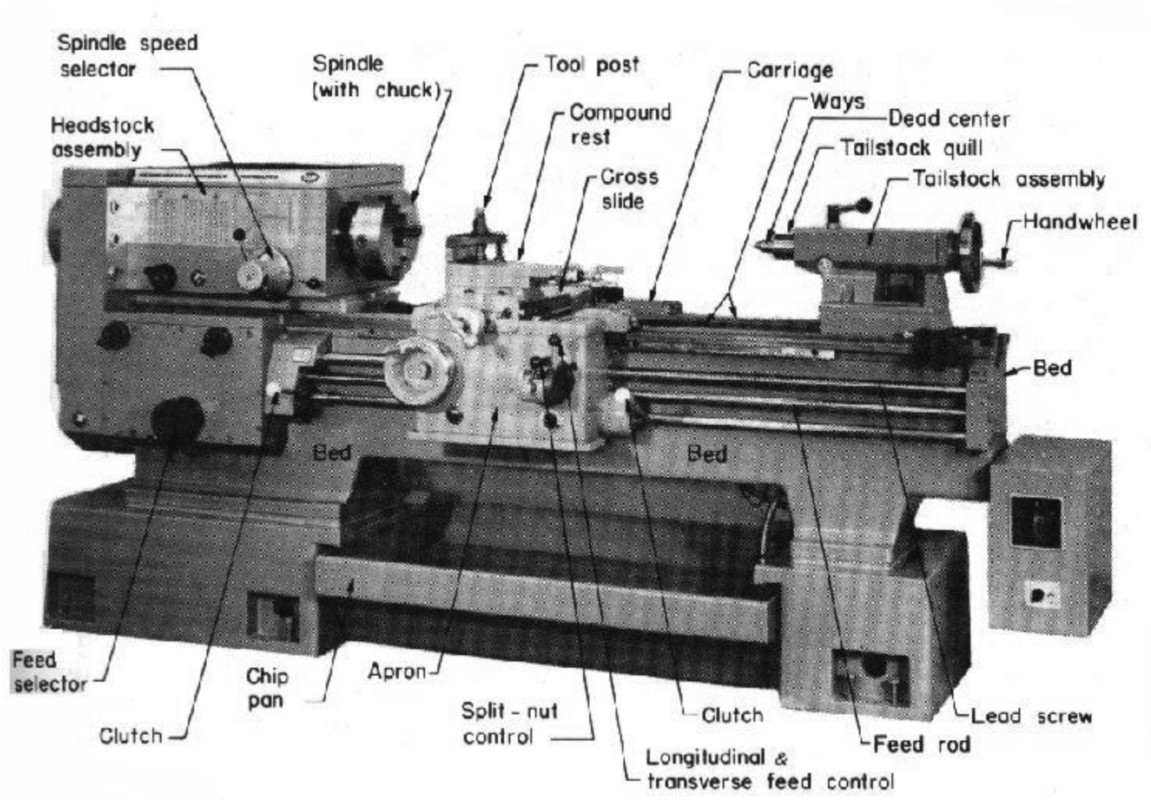


Figure 4.1 Lathe Machine

4.2 Workpiece:

The workpiece comprised of a 500 x 50 mm cylinder made of high manganese steel. The composition, mechanical and physical properties of the high manganese steel work material are given in the following tables.

Table 4.1: Chemical Composition

Element	C	Si	Mn	S	P	Cr	Fe
%age	1.13	0.40	13.0	0.003	<=0.20	1.6	84.23

Table 4.2: Mechanical Properties

Brinell Hardness No.	220
Yield Strength	380 MPa
Ultimate Tensile Strength	940 MPa

Table 4.3: Physical Properties

Density	7.88 g/cc
Expansion coefficient (0^o-600^oC)	21.5 x 10^{-6} /^oC
Specific Heat	502 J/Kg ^oC
Electrical Resistivity	75 μΩm
Thermal Conductivity	13 W/m ^oC
Magnetic Permeability	1.002

Figure 4.2 Workpiece

4.3 Tool:

The turning operation was done by SNMG carbide insert.

Fig. 4.3: SNMG Carbide insert

4.4 Procedure:

The workpiece was mounted between the head stock and the tail stock. Heating of the workpiece was done with the help of oxygen + LPG flame. During heating the workpiece was made to rotate constantly so as to avoid localization of heat. Excessive heating may cause change in metallurgical properties of the workpiece material. It may also result in melting of the material.

The experiment must be conducted at particular temperatures for different readings. The temperature of the workpiece must be maintained upto a particular value for a single run. The workpiece must be heated until it reaches the desired temperature. Once it has attained the temperature, heating must be discontinued. Else there will be error in readings.

In this experiment automatic heating arrangement was used. The flame torch was mounted on a shaft which was connected to a servo motor. The actual movement of the torch (mounted on the shaft) facilitated the heating and discontinuation of heating of the workpiece. A thermocouple was used to measure the temperature of the rotating workpiece.

A sensor was attached to the thermocouple which was used to convert the analog signal to digital signal for the servo motor. The display panel displayed the temperature at every instant. The desired temperature was set.

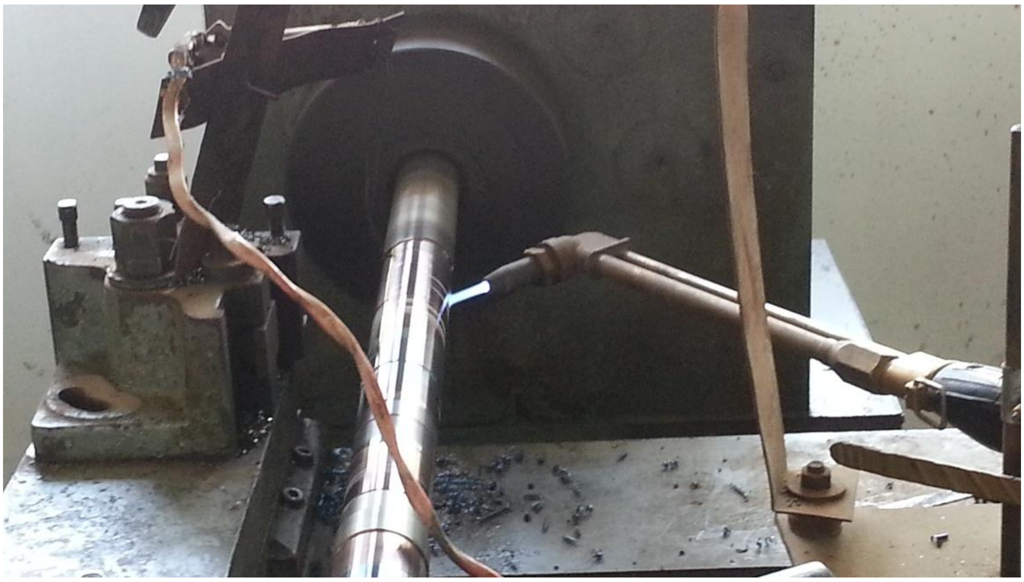


Fig. 4.4: Torch heating the workpiece

When the required temperature was attained the torch automatically withdraws and again returns back when the temperature falls thus maintaining a constant temperature.

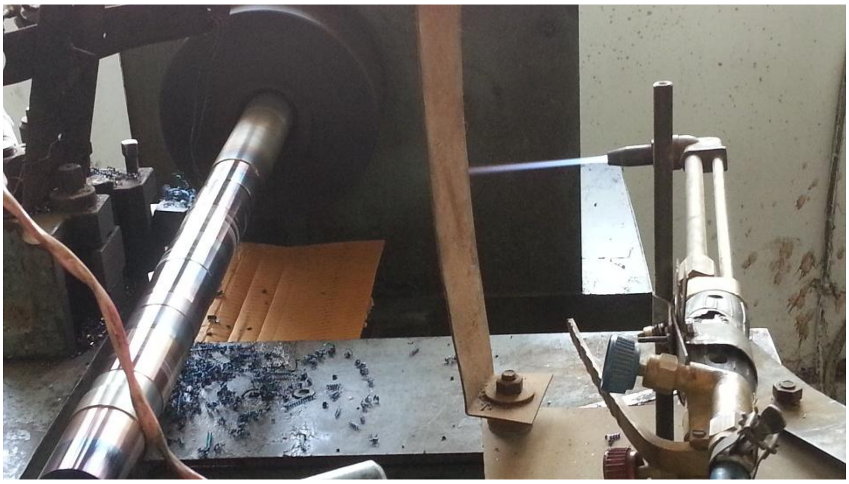


Fig. 4.5: Torch withdrawn

As a result a steady heat source causing uniform heating was maintained by the LPG flame. The flame affected a region on 10 mm width along the circumference of the workpiece.

4.5 Observation:

Heating of the workpiece was done using LPG flame. The temperature of the heat affected zone was maintained using automated heating arrangement.

The following table 4.4 shows the variation of temperature with increasing distance from the heat affected zone when the temperature maintained is 200^{o}C.

Table 4.4

Distance from the source (in mm)	0	5	10	25	50	100
Temperature in ^{o}C	200	162	105	60	37	35

The variation is shown graphically in the following figure 4.6.

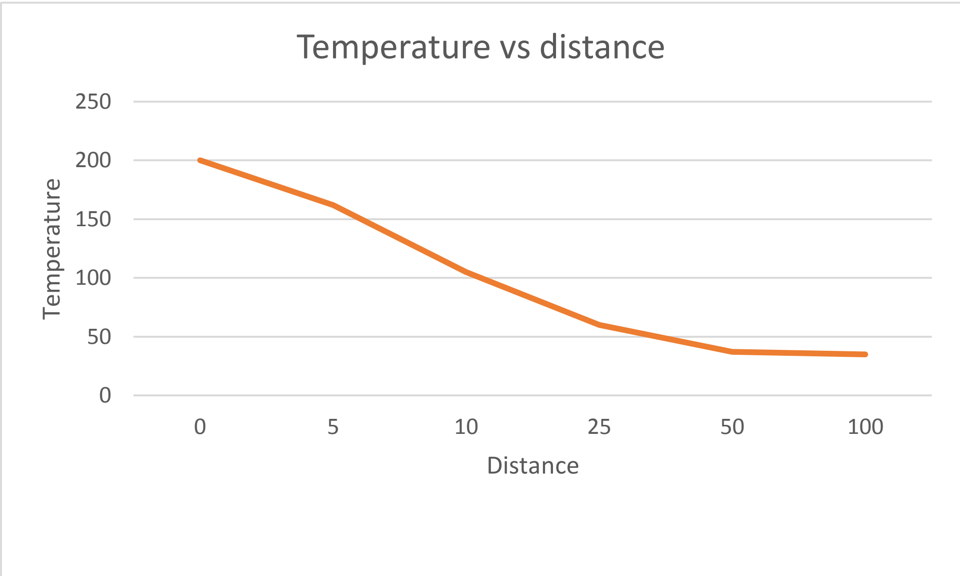


Figure 4.6

Table 4.5: Experimental Data

Serial No.	Cutting Speed V_C (m/min)	Feed S (in mm/rev)	Depth of cut D (in mm)	Temperature of workpiece (°C)
1	21	.05	.5	200
2	21	.05	.5	600
3	21	.7	.5	200
4	43	.05	.5	200
5	21	.7	.5	600
6	43	.05	.5	600
7	21	.05	1.5	200
8	21	.7	1.5	600
9	43	.7	.5	200
10	21	.7	1.5	200
11	43	.7	.5	600
12	43	.7	1.5	600
13	43	.7	1.5	200
14	21	.05	1.5	600
15	43	.05	1.5	200
16	43	.05	1.5	600

Chapter 5

Finite Element Modelling and Analysis

Chapter 5

5.1 Distribution of temperature of workpiece:

(The analysis is performed using ANSYS 14)

5.1.1 Problem Statement:

A cylindrical workpiece of diameter 50 mm and length of 500 mm is rotated in a turning center at 600 rpm. The workpiece is constantly heated with a heat source in movement which is a flame (LPG + O2). We have to design a model in CFD and do analysis to find out the temperature distribution of the workpiece, tool and chip. The temperature of the workpiece surface in contact with the flame is varied from 200-600°C.

Workpiece material= High manganese steel,

Workpiece length= 500 mm,

Workpiece diameter= 50mm,

Rotational speed N= 600 rpm,

Flame travel= 0.1 mm/rev,

Feed = 0.1 mm/rev.

Table 5.1 Chemical Composition of Workpiece (High Manganese steel):

Metal	Mn	C	Si	Cr	P	S	Fe
%	12.5	1.2	4	1.6	.058	.01	84.23

Table 5.2 Work material properties:

Work material	Density (Kg/mm^3)	Specific heat (J/Kg-K)	Thermal conductivity (W/mm-k)
High Manganese Steel	7.8×10^{-6}	$C_p = 420 + 0.67T$	0.05

5.1.2 3D Modelling:

A cylindrical workpiece is modelled in ansys having the following dimensions.

Diameter: 50 mm

Height: 500 mm

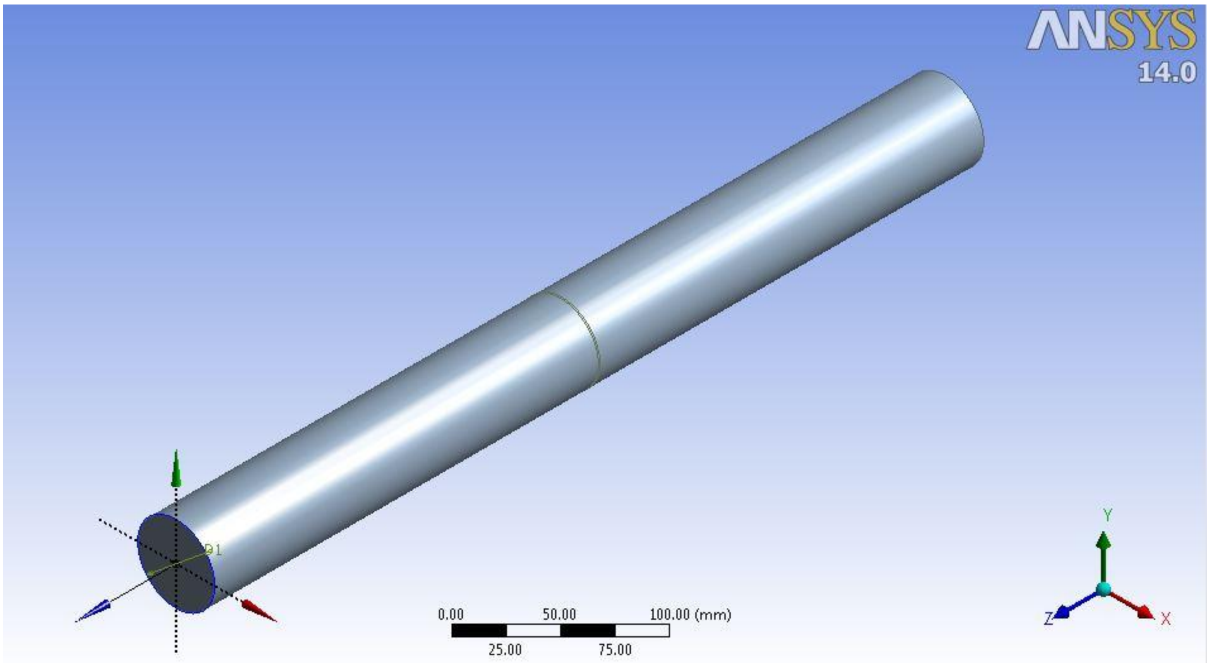


Figure 5.1 3D Model of workpiece

In this analysis we assume a uniform heat source of temperature 500^{0}C acting along a width of 10 mm along the surface of the workpiece. In the above figure a small circle can be seen (from z=245 mm to z= 255 mm) which is the heat affected region.

Since the heat source is uniform and heat flows uniformly through the workpiece 2D analysis is conducted by taking the following:

- Radial cross section (Circular cross section)
- Axial cross section (Axisymmetric Rectangular cross section)

5.1.3 Circular cross section:

A circle of radius 50 mm is taken. Material properties of High manganese steel as mentioned above is applied. The surface is meshed by taking element size equal to .25 mm. The element taken is Quad 4 Node 55.

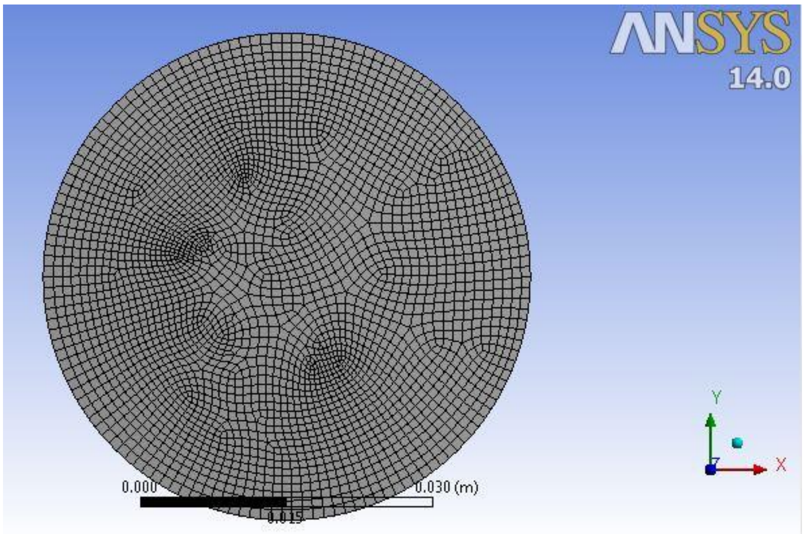
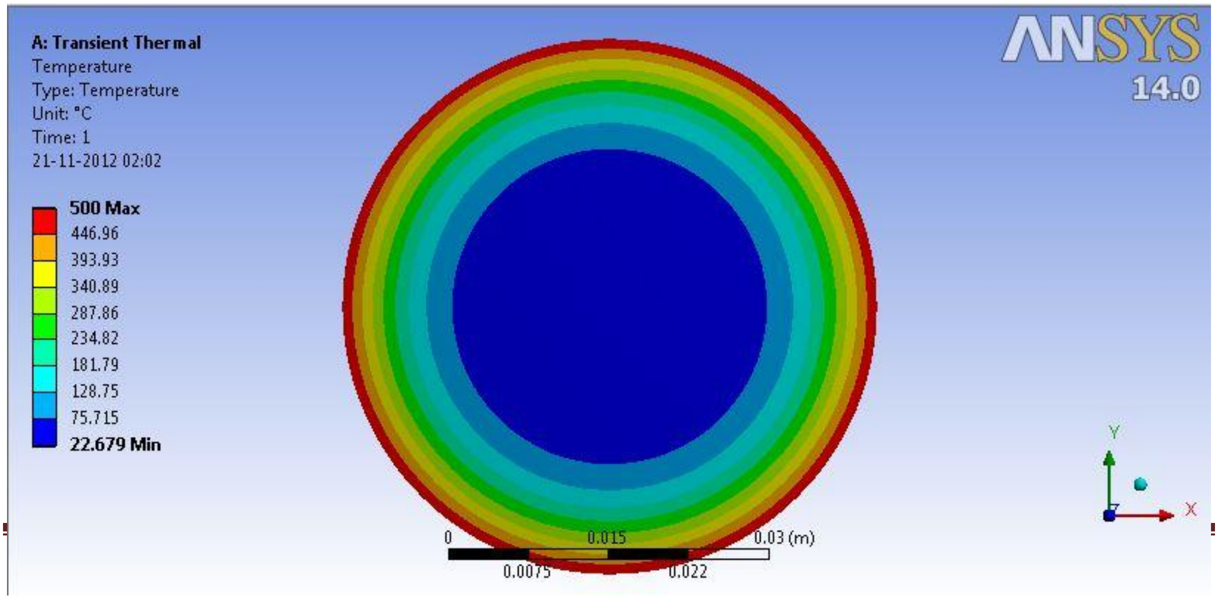


Figure 5.2 Circular Cross section

Initial temperature of the material is 22^0C. A temperature of 500^0C is applied on the outer surface for 1 second.

Figure 5.3 Temp Distribution along the Circular Cross Section

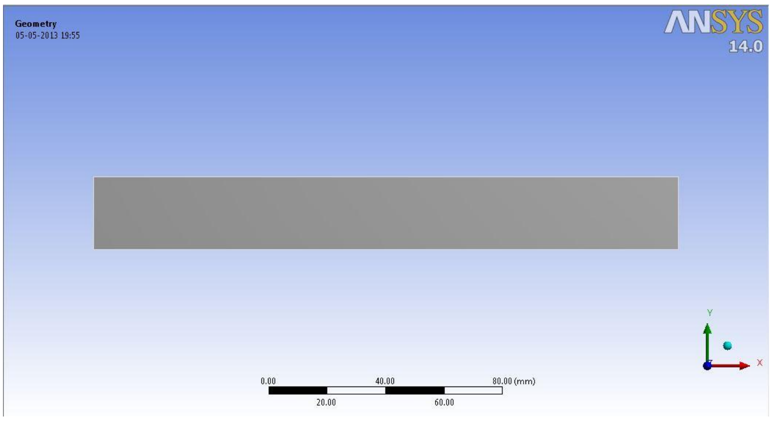


5.1.4 Axisymmetric Rectangular Cross section:

A rectangle of dimensions 200 X 25 mm is taken. Material properties of High manganese steel as mentioned above is applied. The surface is meshed by taking element size equal to 1 mm. The element taken is Quad 4 Node 55.

For a symmetric body axisymmetric modelling gives the same result as the 3D model. It is preferred over the 3D model as for the same result computational time required is less. Rotating the axisymmetric planar model about the axis gives the complete 3D model.

Figure 5.4 Axisymmetric Rectangular Cross section



Initial temperature of the material is 22^0C. A temperature of 200^0C is maintained at the heat affected zone for 60 seconds. The following figure shows the temperature distribution after 60 seconds.

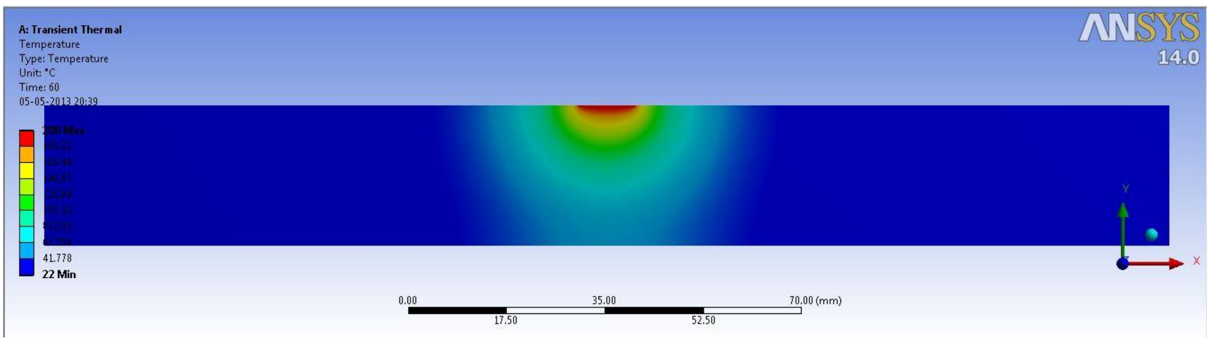


Figure 5.5 Temp Distribution

5.1.5 Temperature distribution along specific regions using PATHS:

A path is categorized as a form of construction geometry and is represented as a spatial curve to which one can scope path result. The results are evaluated at discrete points along this curve.To analyse the temperature distribution six paths are being created. The centre of the flame is taken as the starting point (0, 0).

Path 1: From centre of the flame (0, 0) to x = 100 mm.

Path 2: From 15 mm below the surface (0, -15) to x = 100mm (100, -15).

Path 3: From 25 mm below the surface (0, -25) to x = 100mm (100, -25) i.e. along the axis.

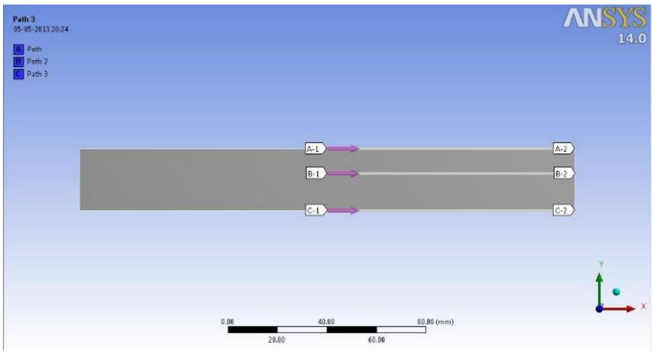


Fig 5.6: Paths 1, 2 and 3

Path 4: From centre of the flame (0, 0) downwards to y = -25 (0, -25).

Path 5: From (25, 0) to (25, -25)

Path 6: From (50, 0) to (50, -25)

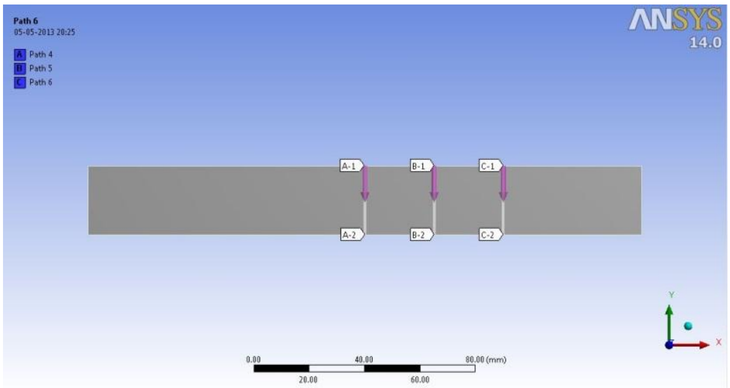


Fig 5.7: Paths 4, 5 and 6

Following figures show the temperature distributions:

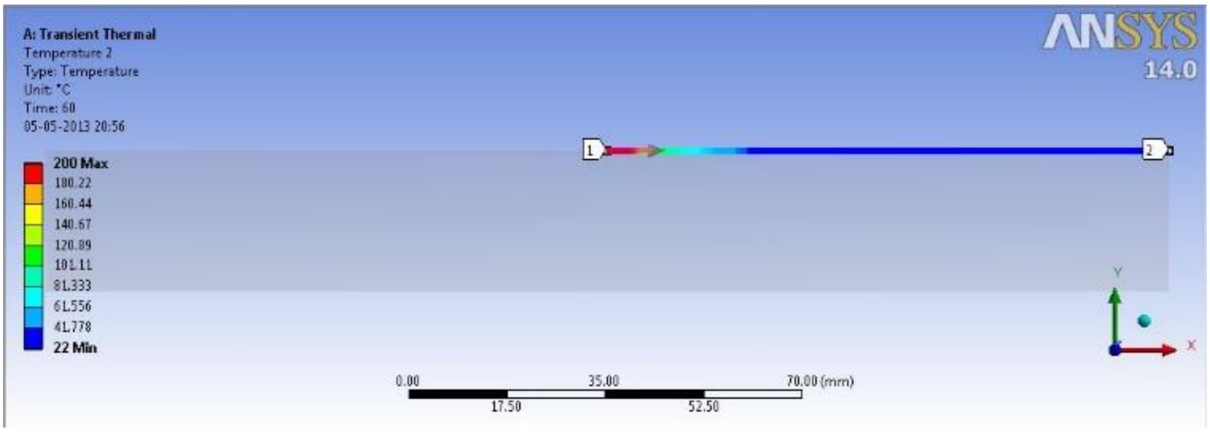


Fig 5.8: Path 1

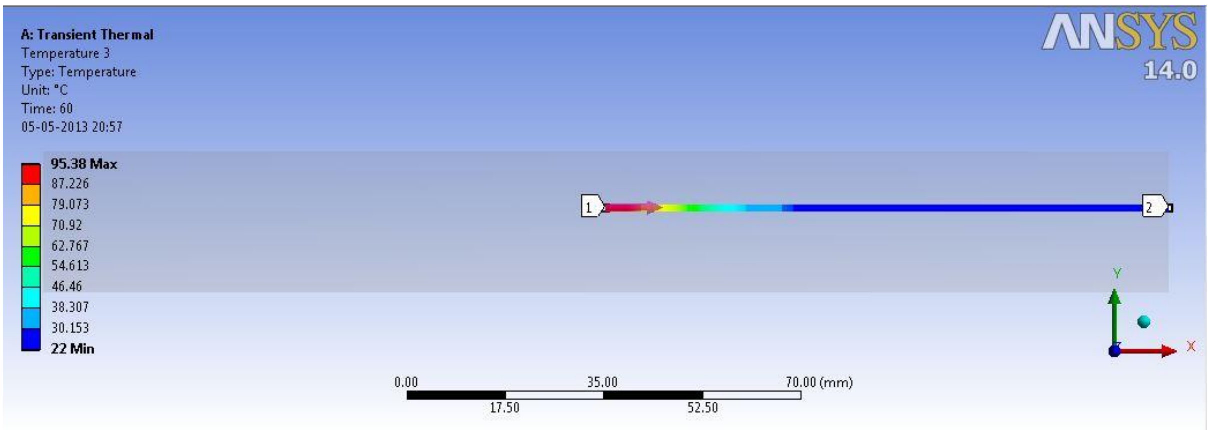


Fig 5.9: Path 2

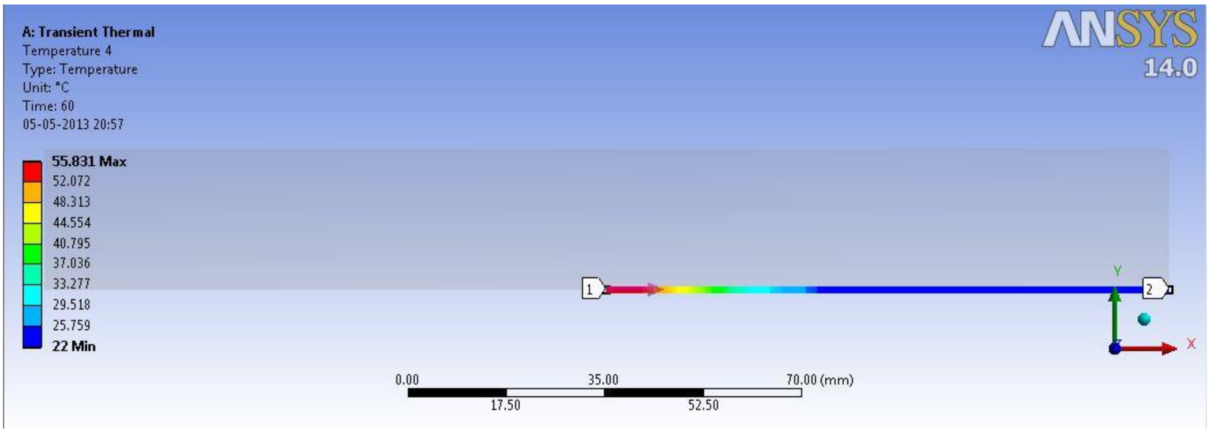


Fig 5.10: Path 3

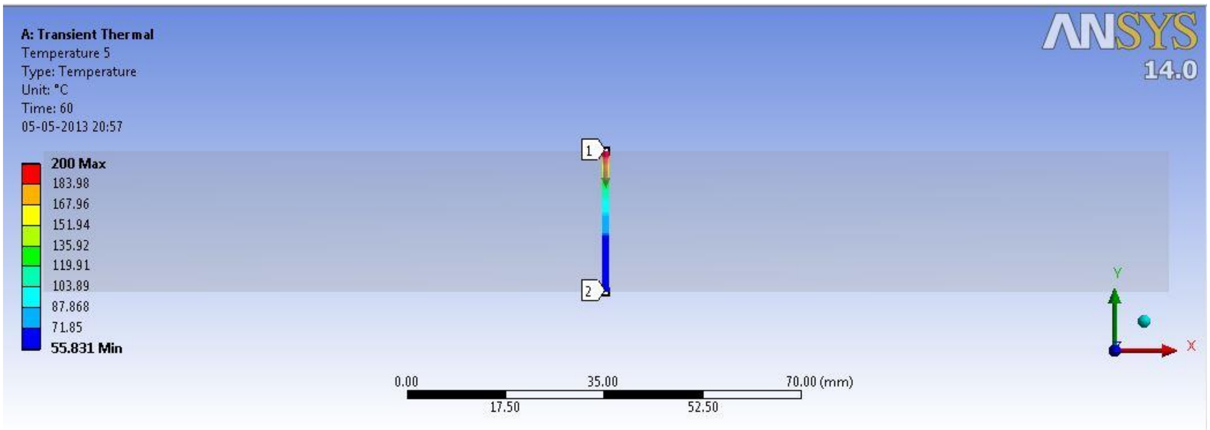


Fig 5.11: Path 4

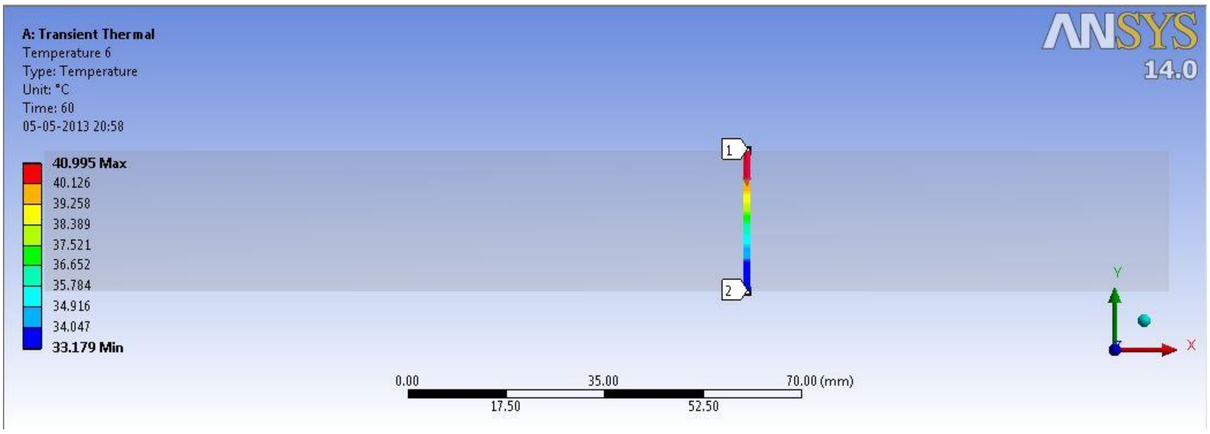


Fig 5.12: Path 5

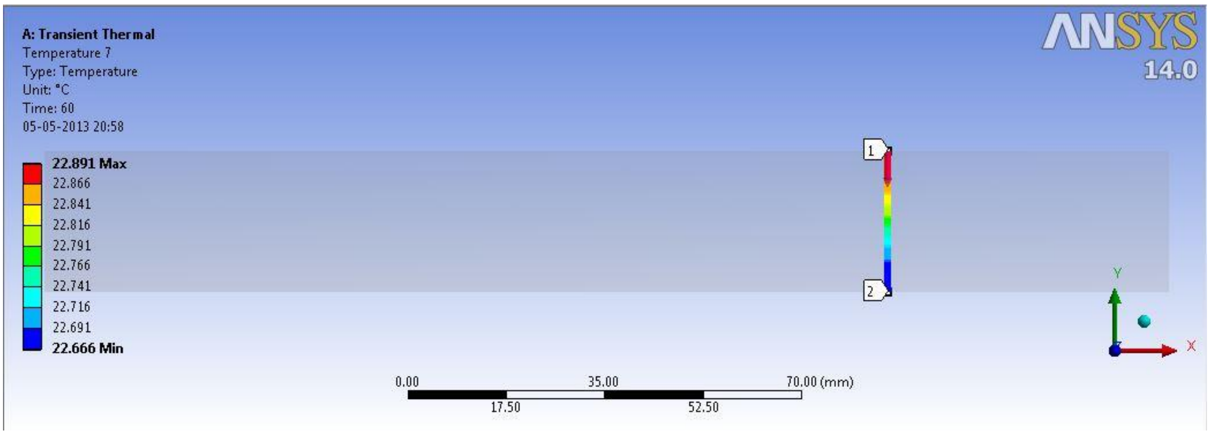


Fig 5.13: Path 6

The values are obtained from the above analysis and the following graphs are plotted.

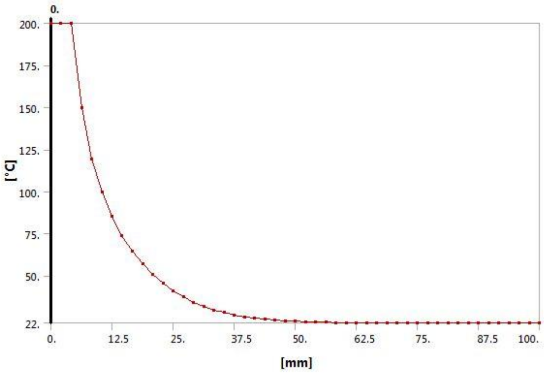


Fig 5.14: Path 1

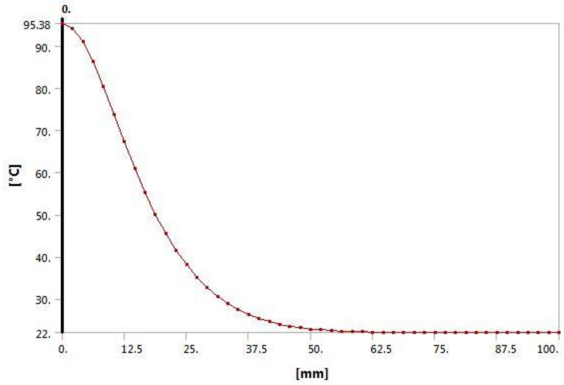


Fig 5.15: Path 2

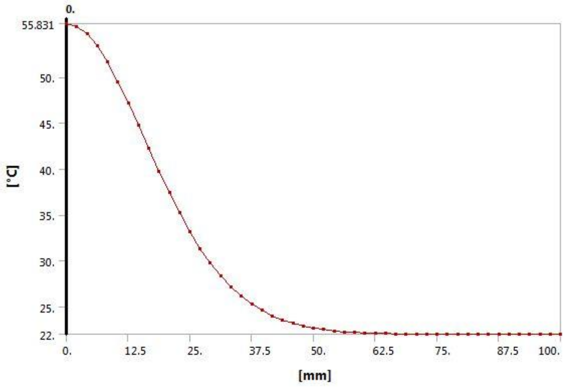


Fig 5.16: Path 3

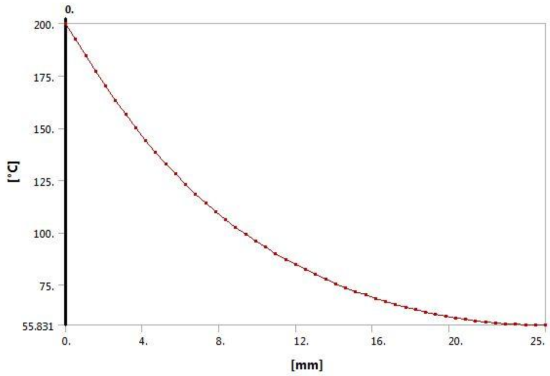


Fig 5.17: Path 4

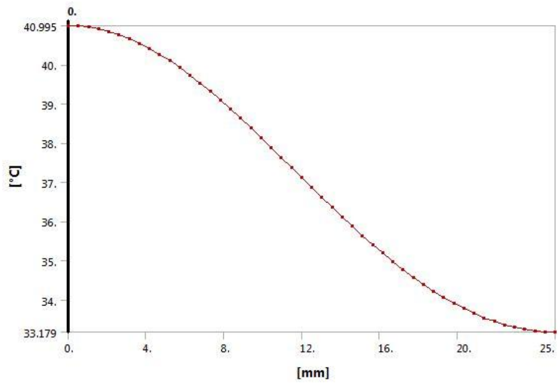


Fig 5.18: Path 5

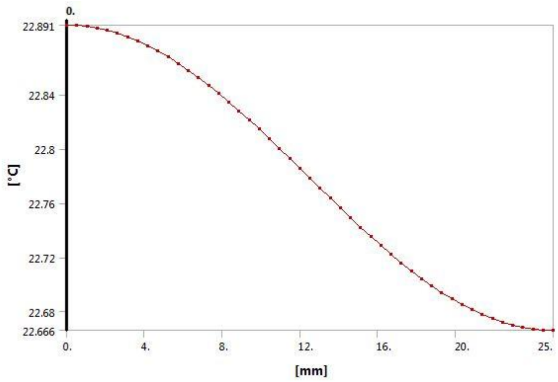


Fig 5.19: Path 6

The following graphs shows the variation of temperature distribution from x = 0 to x = 100 along three different paths (1, 2 and 3) i.e. y = 0, y = -15, y = -25. (Combining first three graphs)

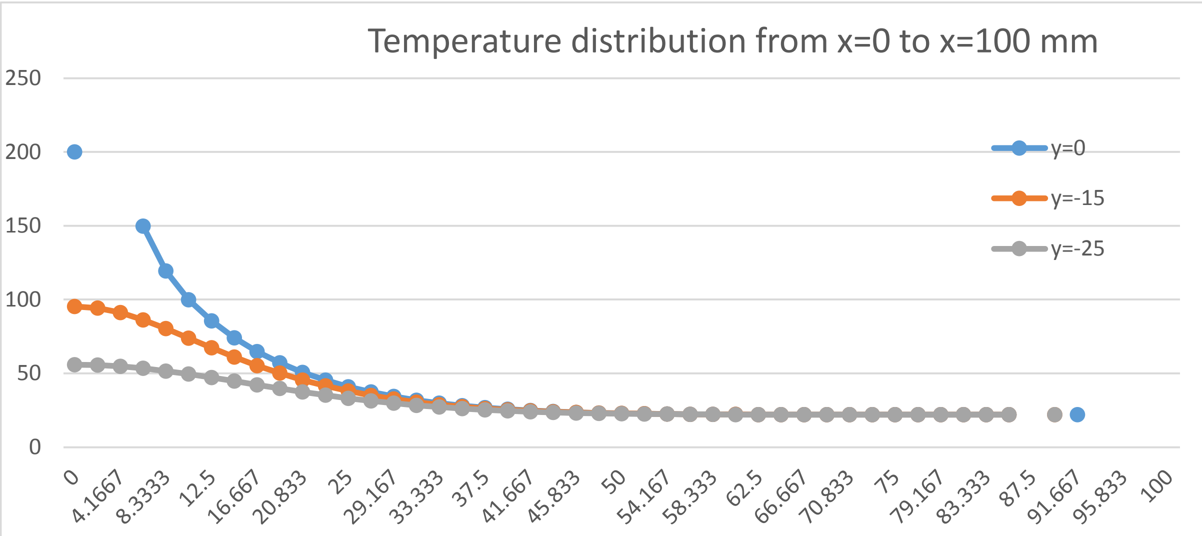


Fig 5.20: Combining Fig 5.14, 5.15 and 5.16

The following graph shows the variation of temperature distribution from y = 0 to y = -25 along three different paths (4, 5 and 6) i.e. x = 0, x = 25, x = 50. (Combining last three graphs)

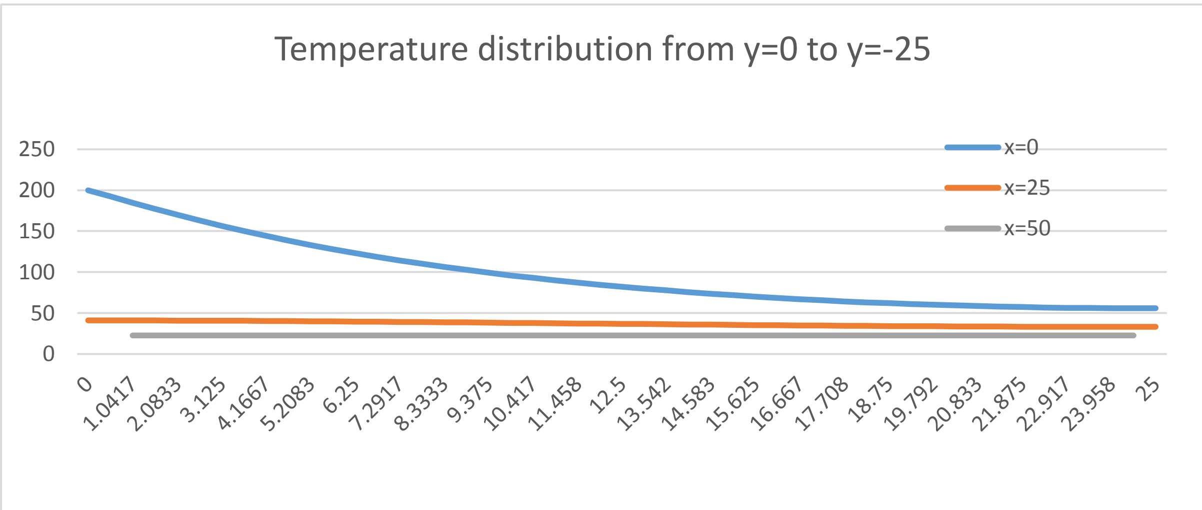


Fig 5.21: Combining Fig 5.17, 5.18 and 5.19

5.2 Modelling of Chip Tool Interface:

(The analysis is performed using DEFORM-2D)

5.2.1 Chip Tool Interface:

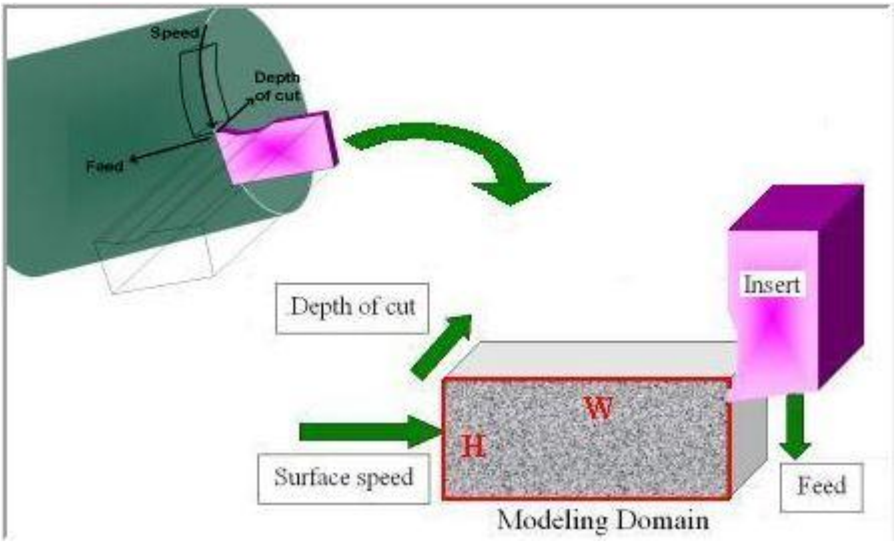


Fig 5.22: Chip tool Interface

H = 5 mm

W = 1 mm

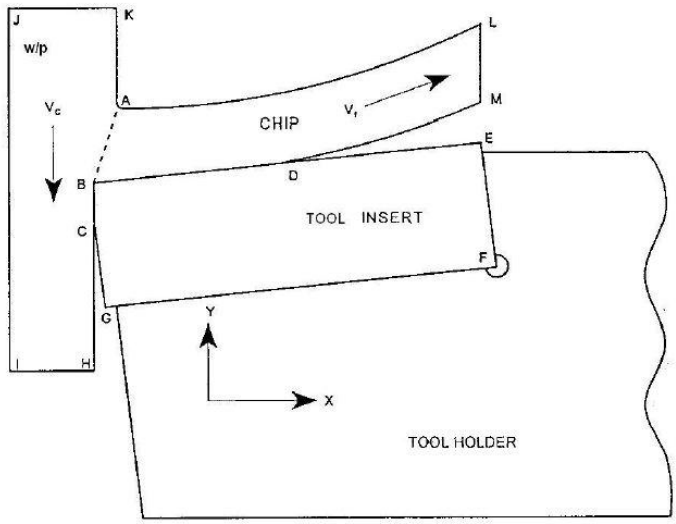


Fig 5.23: Chip tool Interface (2D View)

DEFORM 2D was used to model the tool and workpiece. Various input parameters such as cutting velocity, feed and workpiece temperature were taken. The output parameters obtained are given below.

- Temperature of chip tool interface
- Effective strain
- Effective stress
- Cutting force
- Thrust force
- Tool wear rate

The input parameters were varied shown in the following table 5.3.

	Cutting speed m/min F_C	Feed (mm/rev) s	Temperature (°C) t
1..	21	.05	200
2.	43	.7	600

Table 5.3

For the 1st model: F_C = 21 m/min

S = .05 mm/rev

T = 200°C

For the 2nd model: F_C = 21 m/min

S = .05 mm/rev

T = 600°C

The following figure are obtained for different temperature values i.e. t=200°C and t=600°C.

5.2.2 Temperature Distribution:

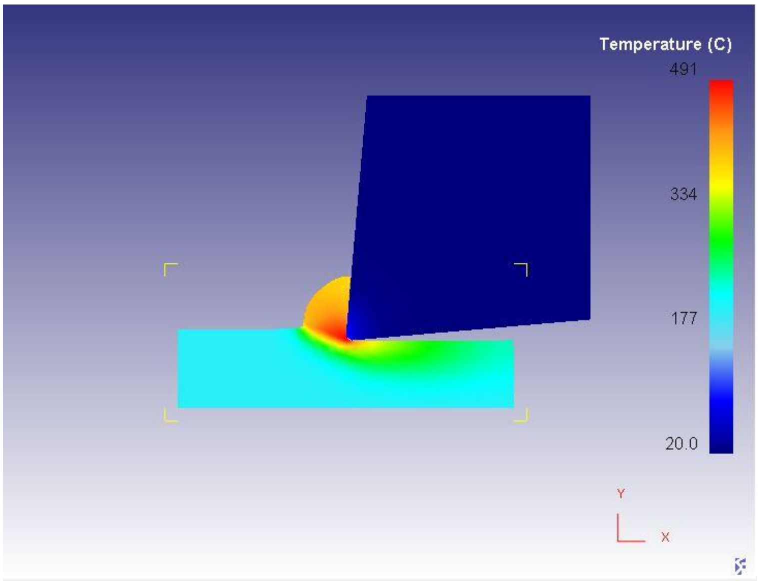


Fig 5.24: 200°C

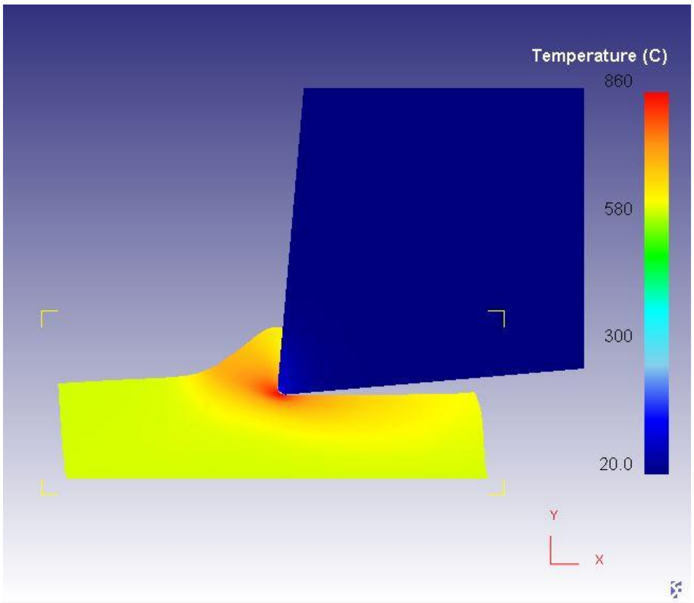


Fig 5.25: 600°C

5.2.3 Effective Strain:

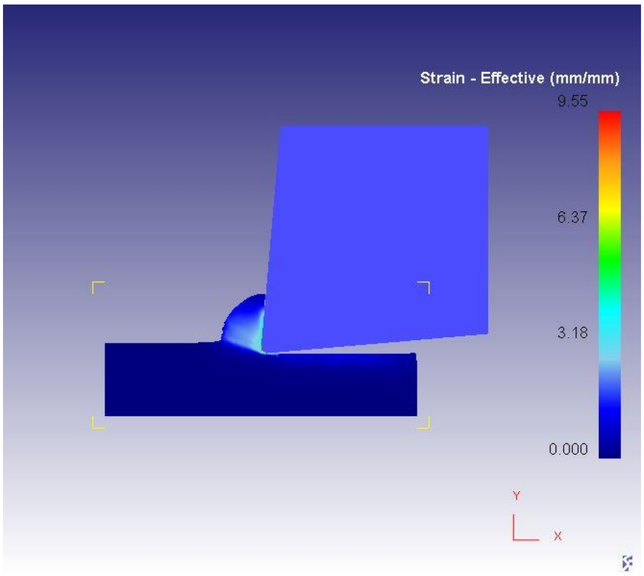


Fig 5.26: 200°C

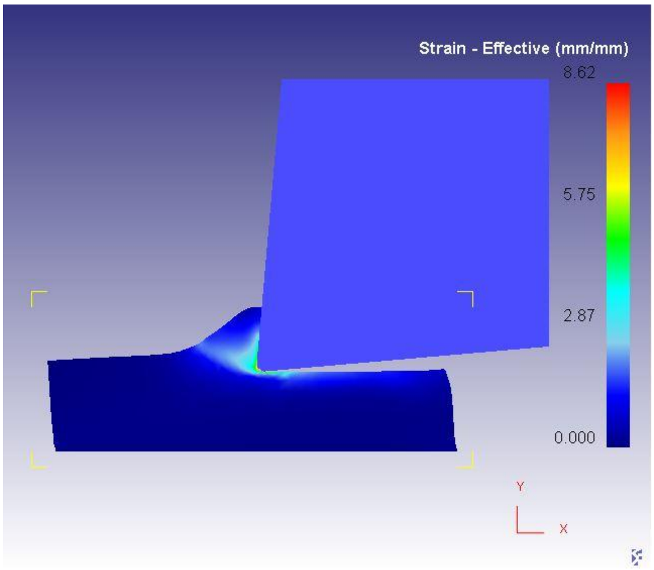


Fig 5.27: 600°C

5.2.4 Effective Stress:

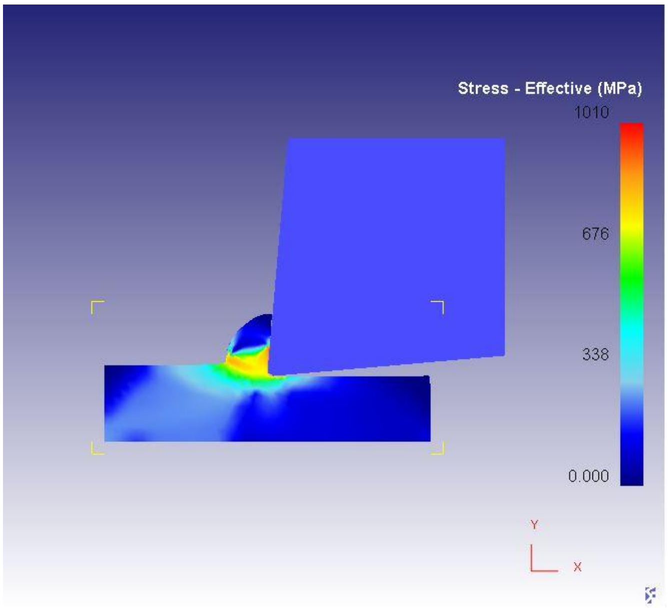


Fig 5.28: 200°C

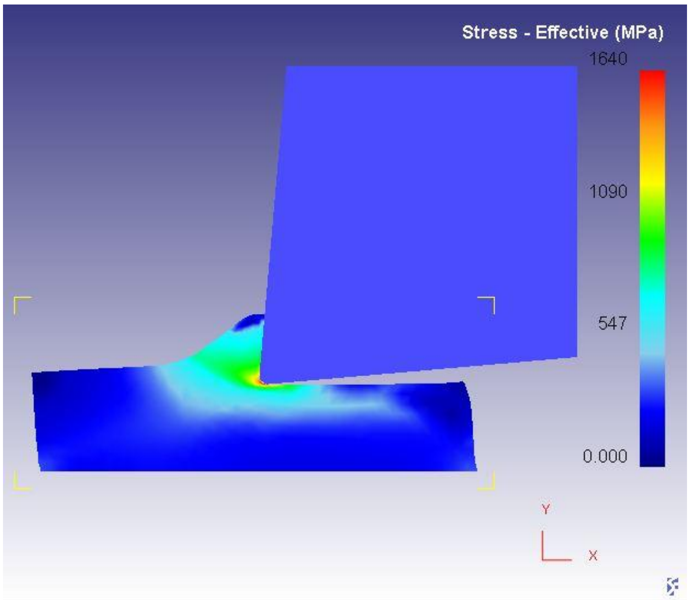


Fig 5.29: 600°C

5.2.5 Tool Wear Rate:

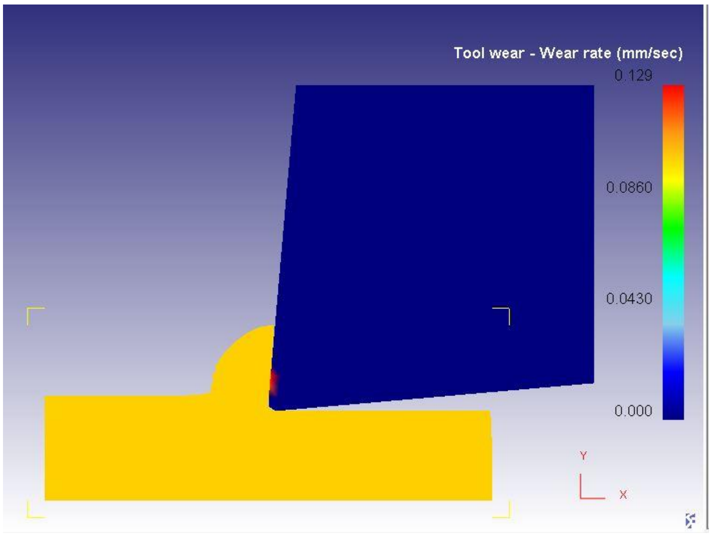


Fig 5.30: 200°C

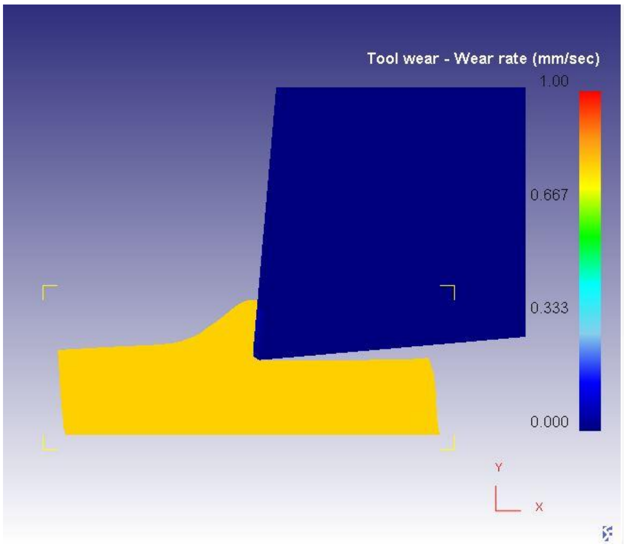


Fig 5.31: 600°C

5.2.6 Cutting Force:

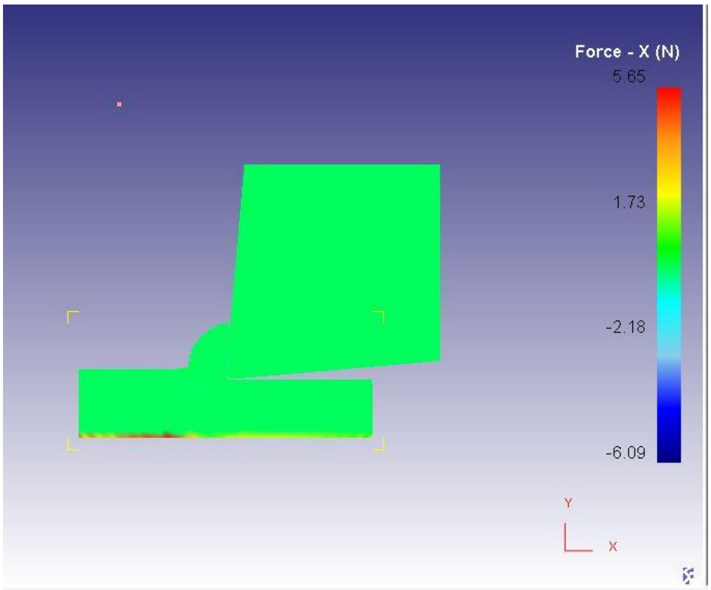


Fig 5.32: 200ºC

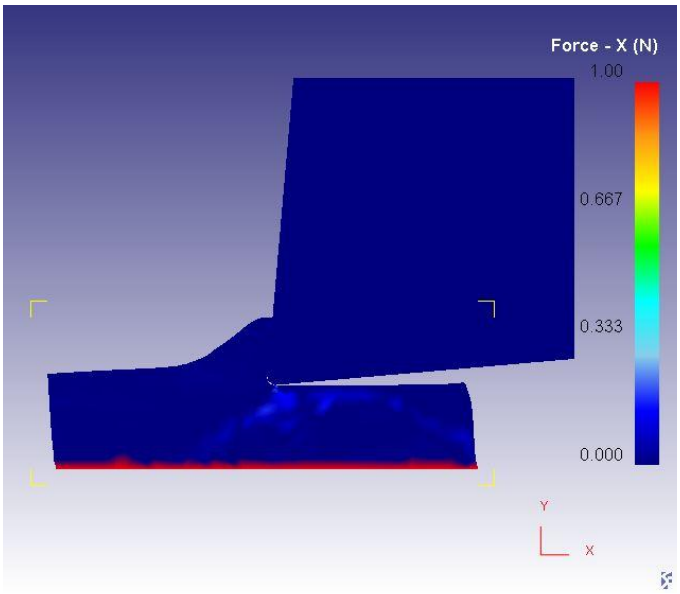


Fig 5.33: 600ºC

5.2.7 Thrust Force:

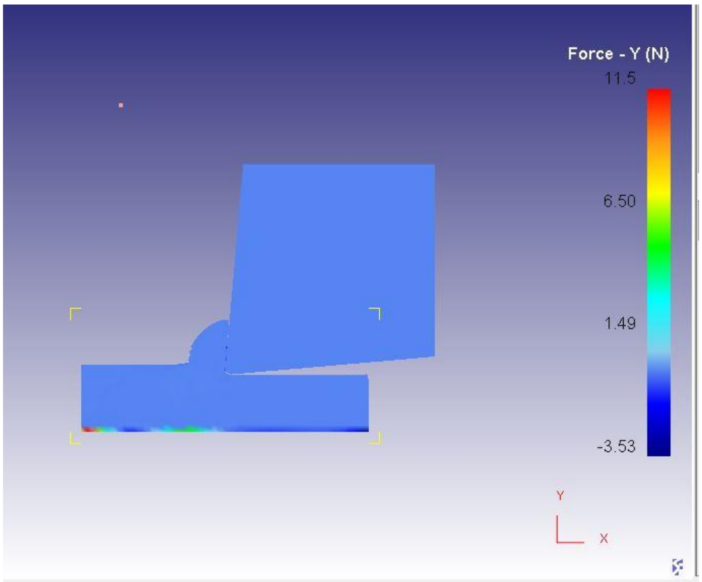


Fig 5.34: 200ºC

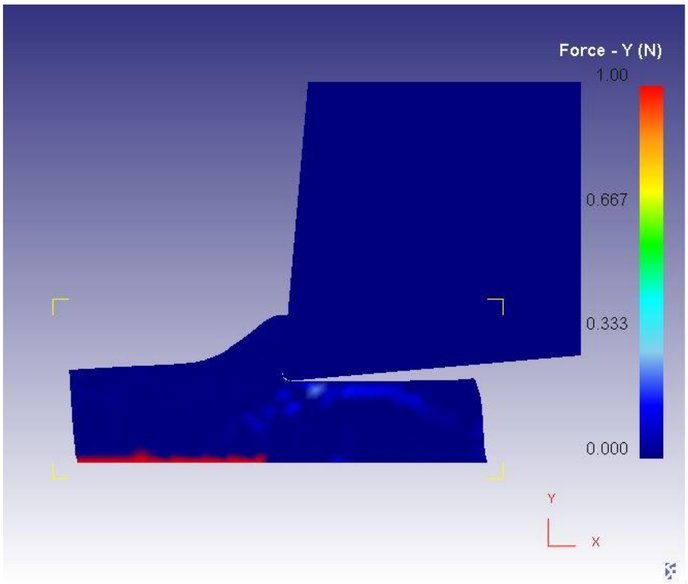


Fig 5.35: 600ºC

Chapter 6

Results and Discussions

Chapter 6

6.1 Temperature distribution of workpiece:

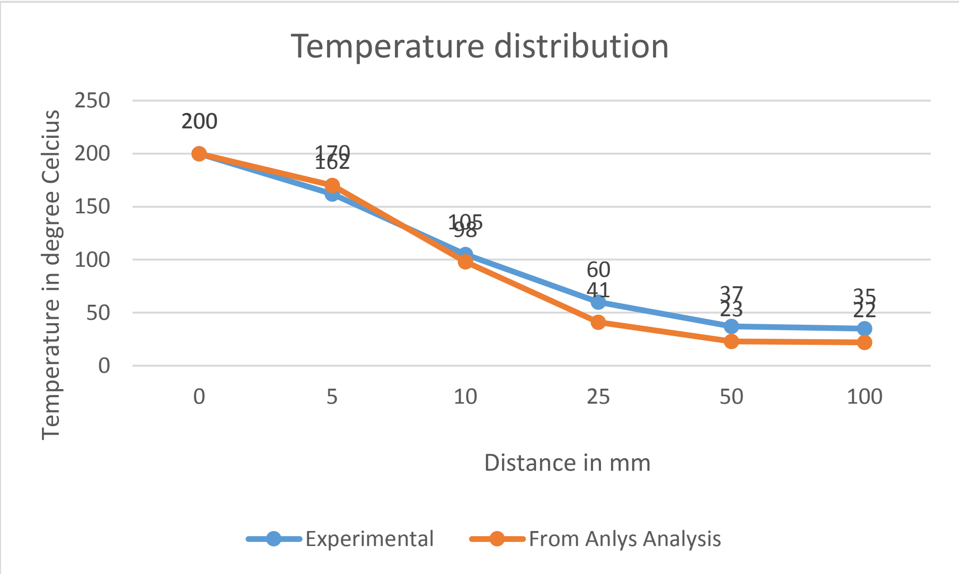


Fig: 6.1: Temp distribution of workpiece

Here the error arose because the modelling was done by taking the room temperature as 22ºC but during the conduction of the experiment the room temperature was above 30ºC.

6.2 Temperature distribution at the chip tool interface:

A point is considered at the chip tool interface and its values of temperature, strain and stress are calculated for different values of cutting speed and temperature (feed and depth of cut remaining same).

V_C = 21m/min, 43 m/min

Temp = 200ºC, 600ºC

Feed = .05 mm/rev

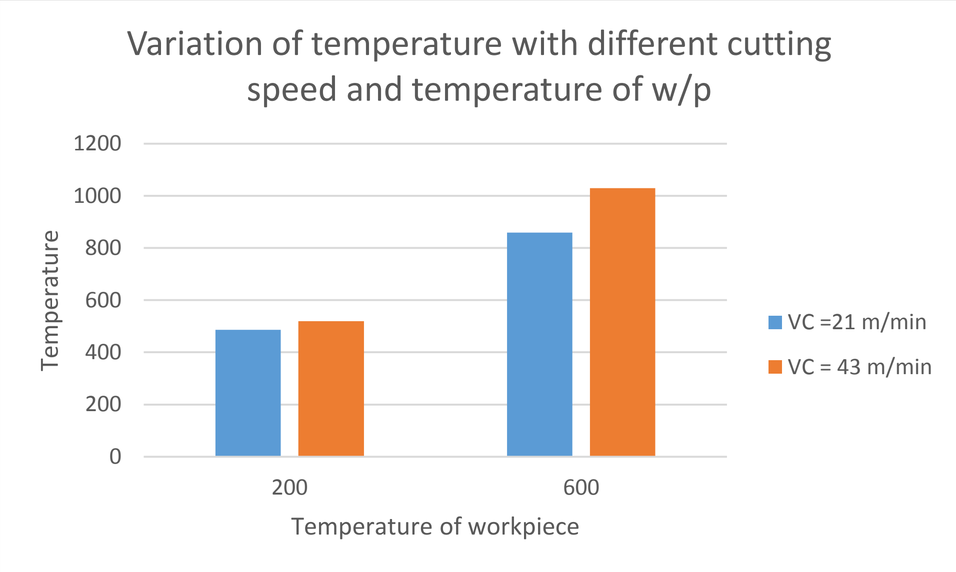


Fig 6.2

It can be seen that the temperature of the chip tool interface increases with increase in cutting speed (Figure 6.2).

6.2.3 Effective Strain:

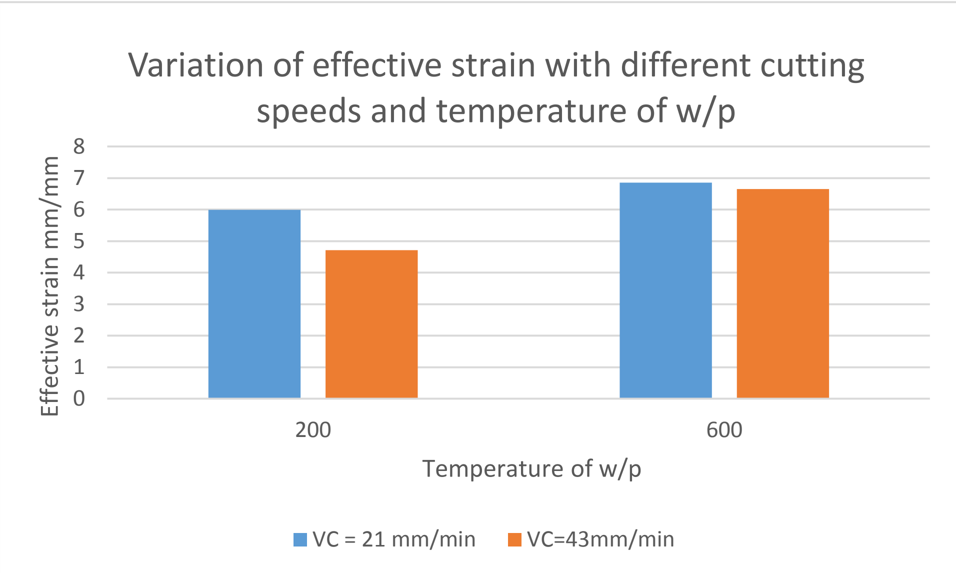


Fig 6.3

It can be seen that the effective strain decreases with increase in cutting speed, other parameters remaining same. But for a given cutting speed the effective strain increases with increase in temperature of workpiece (figure 6.3).

5.2.4 Effective Stress:

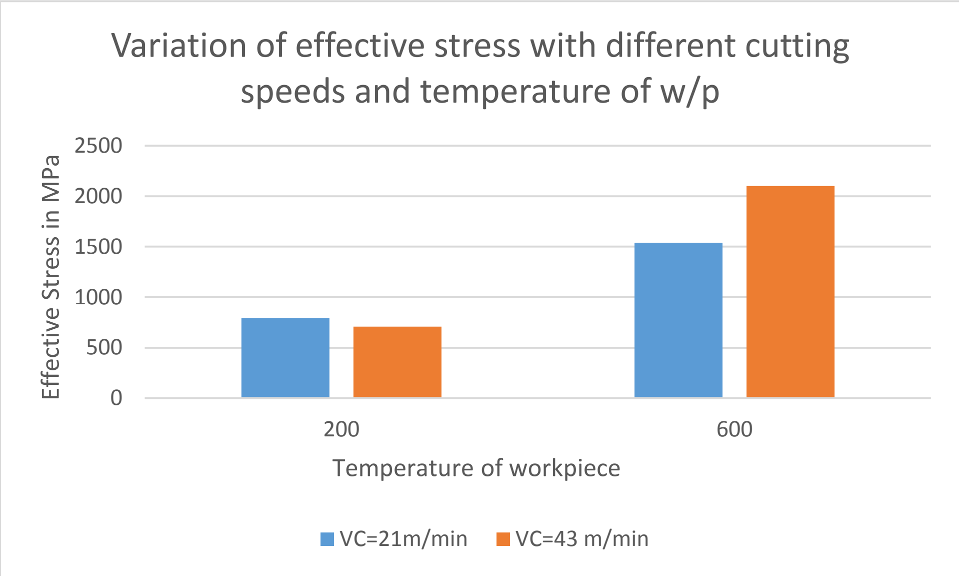


Fig 6.4

With increase in temperature the effective stress increases (figure 6.4).

5.2.5 Tool Wear Rate and Cutting Forces:

It can be observed from the figures of tool wear that a minute red region representing high tool wear rate is seen on the model where the temperature of the workpiece is taken to be 200^{o}C. On increasing the temperature to 600^{o}C this region vanishes. Hence it can be concluded that on increasing the temperature of the workpiece the tool wear rate decreases.

Similarly from the figure of Cutting force and thrust force it can be concluded the on increasing the temperature of workpiece the cutting forces decrease.

Chapter 6

Conclusion and Scope for Future Work

Chapter 6

6.1 Conclusion

The following conclusions can be made:

- The temperature of the chip tool interface increases with increase in cutting speed.
- Effective strain decreases with increase in cutting speed, other parameters remaining same. But for a given cutting speed the effective strain increases with increase in temperature of workpiece
- With increase in temperature the effective stress increases
- On increasing the temperature of the workpiece the tool wear rate decreases.
- On increasing the temperature of workpiece the cutting forces decrease.

Hot machining process can be used for machining hard materials. But there are some shortcomings. The setup with a heating source should be available. Trained personnel should use the flame. Heat should be uniformly distributed throughout the cross section and care should be taken not to overheat the work material as it will change the metallurgical properties.

6.2 Future Scope

- All the experimental values could not be compared.
- The tool for modelling was used from the DEFORM library. In order to get accurate results the tool must be modelled.

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